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A CROWDSOURCED DESIGN EXPERIMENT USING FREE-HAND SKETCH DESIGN METHOD BASED ON THE CDESIGN FRAMEWORK

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Abstract

In the age of ubiquitous, global Internet the process of product design is no longer confined to individuals or groups of employees but can be carried out by the combined efforts of many people through systematic, iterative processes. Although the literature reports several qualitative experiments, the process of specifying the details of an Human-based Genetic Algorithms process has been less considered. This paper reports the results of an experimental assessment of a generative design task that has been crowdsourced by an HBGA process specified by application of the Crowdsourced Design (cDesign) framework.Additionally, the application of free-hand sketch method in crowdsourced design task is firstly introduced based on the cDesign framework. The paper first describes the cDesign framework used to structure the creation of a car key fob design task on a commercial crowdsourcing platform and then presents the results to test the effectiveness of the free-hand sketch method in cDesign. The paper concludes that the free-hand sketch method can be well applied in the HBGA cDesign framework and cDEC assessment methodology effectively to generate creative design solutions.

Keywords: Crowdsourcing, Design process, Conceptual design

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1 INTRODUCTION

In the information age, design can be a product not only of individuals but may also result from the combined efforts of many people. Although such collaborative design systems are well documented in the literature for design activities carried out by, say teams of professional engineers and architects (Whitfield et al., 2002) less is known about the potential of distributed, anonymous, crowd-based collaboration in creative tasks. In contrast to the established processes academic research into crowdsourced design has investigated the power of iteration, competition, reward and combination processes (Wu et al., 2014b; Lixiu Yu and Nickerson, 2011), and the systematic framework (i.e., a design methodology) called cDesign (Crowdsourced Design) has recently been reported (Wu et al., 2015). The aim of this paper is to illustrate how the free-hand sketch is used in crowdsourced design tasks based on the authors' cDesign Framework through its application to key fob design tasks and validate the ability of cDEC to create effective product design specifications.

1.1 Crowdsourcing

In 2006, "crowdsourcing" was defined by Jeff Howe as "the act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call"(Howe, 2006). Then since 2006, the Human-based Genetic Algorithms (HBGA) has emerged as the principle way to support design using crowds as the next section describes the HBGA requires designs to be combinable (i.e., merge distinct features) and also evaluable. The paper is structured as follows: the coming paragraphs present a brief review of crowdsourcing's application in design domain, followed by an overview of the cDesign Framework (Section 2); then the paper presents the detailed processes of the application of the framework in a car key fob design task (Sections 3 and 4). In Section 5, there is a discussion of the outputs of the final design quality against the 1st generation design quality, and a brief comparison of the experiment results and the reported work. Finally, the paper ends with some conclusions and discussions of the limitation of the experiment and recommendations for the future work (Section 6).

1.2 Collaborative crowdsourced design

Unlike the competition model system (i.e., Taskcn (Anon.; Wu et al., 2014a)) where the design work is ultimately done by individuals, collaborative design requires the merging or selective combination of ideas (Yang et al., 2008; Liu and Yang, 2011). One of the most impressive methodologies to emerge for collaborative, crowdsourced design is the Human-based Genetic Algorithms (HBGA) method that has been used for generative innovation tasks (Yu and Nickerson, 2011; Yu and Nickerson, n.d.; Yu and Sakamoto, 2011). The approach uses selective combinations to develop creativity (Osborn, 1957; Amabile n.d.), and has been applied to a number of different applications (Yu and Nickerson, n.d.; Yu and Nickerson, 2011; Bao et al., 2011). This is a theoretically appealing approach because it has been suggested by some researchers that creative design comes from combinations (Amabile, n.d.). In the HGBA, new ideas are basically separated into different generations. In the first generation, participants from the crowdsourcing platform create the first group of designs. Then a second crowd evaluates the first generation and chooses several pairs (that are judged to be the "best") for the combination process to construct the second generation (i.e., generation 1 evaluation). In generation 2, some of the ideas were selected directly from the top ranked generation 1 designs, and others were collected by combining pairs chosen from the first generation (i.e., generation 2 combination). Then, the third generation applies the evaluation process to the second generation combination process again to create generation 3 (Yu and Nickerson, n.d.; Yu and Nickerson, 2011). So, iteratively, generation after generation, new designs can evolve each slightly better than the preceding ones.

1.3 Crowdsourced Design Evaluation Criteria (cDEC)

During the cDesign process, two of the important factors which will affect the design quality are design specifications (cDS) and design evaluation criteria. The importance of the design specifications is reported in a large number of traditional design methodologies (i.e., Pugh's Total Design Model), as well as the design evaluation criteria (Hart et al., 2003). In this work, the crowd is used to both establish the design specifications and the evaluation criteria for the crowdsourced design tasks.

Although the cDesign Framework has been reported as a design model for 2D & 3D room layout designs (Wu et al., 2014a; Wu et al., 2015), it has not been applied to designs as free-hand sketches. So, the objectives of this paper are: 1, to validate if the cDesign Framework can be applied to create a product design from free-hand sketches; 2, to investigate if HBGA can improve the design quality in the cDesign Framework guided by the cDEC method. The hypothesis of the result is that the cDesign Framework can specify a process that produces improve design quality over a number of generations.

2 METHODOLOGY - THE FUNDAMENTAL CDESIGN FRAMEWORK

Despite its apparent diversity the process of mechanical design has been formalized by models such as Pugh's "Total Design" (Pugh, 1991) or Pahl and Beitz's method (Pahl et al., 2007). These models of the design process provide a reference framework which enumerate the criterial steps and allow previously "ad hoc" activities to be structured and managed. The cDesign model presented in this section is motivated by the desire to provide a similar structure to the process of creating crowdsourced design tasks. Thus, the objective of the framework is to define the structure within which a particular refinement or evaluation process (i.e., Yu's HBGA) can be applied. The cDesign model details all the stages of crowdsourced design activity starting from the crowdsourced design specification, and ending with the evaluation of the resulting design. The model is shown schematically in Figure 1 and consists of four major stages: Specification, Prototype, Execution and Evaluation. The framework provides a structure for describing the issues considered by the creator of a crowdsourced design task (rather than being, say, a provable optimum model). The following sections provide a qualitative description of the stages before the experimental work in support of the design evaluation process used in Stage 2, 3 and 4 is presented. Each of these stages can be expanded into a specific checklist of issues and options that must be addressed by the creators of crowdsourced design tasks, which are shown in the following paragraphs.
Stage 1: The Specification Stage comprises tasks such as: Platform Selection, Design Tool Selection, "Crowd" Selection, Methodology Selection and Design Workflow. Every design task needs a crowdsourcing platform to host the process and the choice of crowdsourcing platform will reflect the nature of the task: some of the design work can be attempted by anyone regardless of education or background, whereas other tasks require specific experience or education. For example, Amazon's Mechanical Turk (MTurk) and ShortTask involve workers from all over the world. In contrast, some platforms are only for workers from one country, for example the Taskcn platform has workers mostly from China. After selection of the platform the choice of design representation or tool is the second most important step. Design tools need to be selected for workers as a consideration of the task itself (i.e., 2D design task – 2D design tools or 3D design task – 3D design tools). There are several considerations of design tool selection which are discussed in the following sections.
Furthermore, the "crowd" provided by a given platform needs to be selected and consideration given to any skills they might require. In parallel to the fundamental decisions on platform, tool and crowd, the methodology to be adopted in the execution process must be determined at this initial stage. For example, the design task processes can be iteratively or non-iteratively executed. Finally, once the methodology is specified the design workflow needs to be discussed (i.e., results' file transfer, shared access to a representation held in the cloud, etc.).

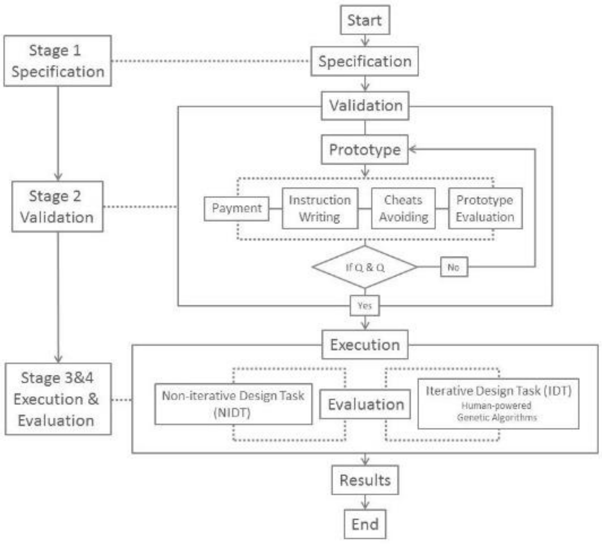

Figure 1. cDesign methodology framework's main stages

Stage 2: Without prior experience of running similar tasks many of the choices made in the specification stage will be educated guesses whose effectiveness is uncertain. There are 6 implementation decisions that need to be specified and validated in Stage 2: the payment for participants; time to undertake the task; clarity of the task instruction; the method of submitting results and the manner in which workers who attempt to scam, or cheat, the system should be handled.

The design of the crowdsourcing task is refined through the process of prototype testing until the require Quantity and Quality (Q & Q) of results are being produced. At which point the process moves to the Execution Stage.

Stage 3 & 4: Execution is essential a scaling up of the task for presentation to a larger crowd. The length of the execution stage will be determined by the method set in Stage 1. A competition might last many weeks whereas a Human-based Genetic Algorithms (HBGA) will often cycle through generations of design every few days. In terms of the Evaluation process, regardless of the mechanism used the process ends, with a review of the generated design by a panel of experts who review the crowd's work and select the best outputs. At both the validation and execution stages the ability to accurately evaluate designs is crucial to tasks such as the setting of payment levels (Stage 2) or selecting the best design for iterative improvement (Stage 3). The next sub-section describes an experiment, in terms of the cDesign framework, that was created to investigate the framework's application in the design of a key fob.

3 CAR KEY FOB DESIGN EXPERIMENT EXECUTION

Overall design workflow

Based on the cDesign framework, the overall car key fob design workflow is illustrated as below (Figure 2). The nature of the design brief will determine the platform, design tools, crowd type, methodology and workflow. In this case, a public crowdsourcing platform (MTurk) was selected rather than a specialise site (e.g., GrabCAD for engineering, or Taskcn for graphic design experts). The literature suggests that mTurk can be selected as an effective tool to get work done quickly and at minimal cost. What is more, all people using the internet and having an account on the crowdsourcing platform would be welcome to participate in the design as well as the subsequent evaluation experiments.

In terms of the design tool, as reported, although some 2D online free design tools can be provided to participants, they all impose limitations and constrains on both the crowd and the resulting designs (i.e., difficult to start, getting familiar to the tool before the task, web tech limitations) the authors finally decided to use the free-hand drawing as the design tool in this task.

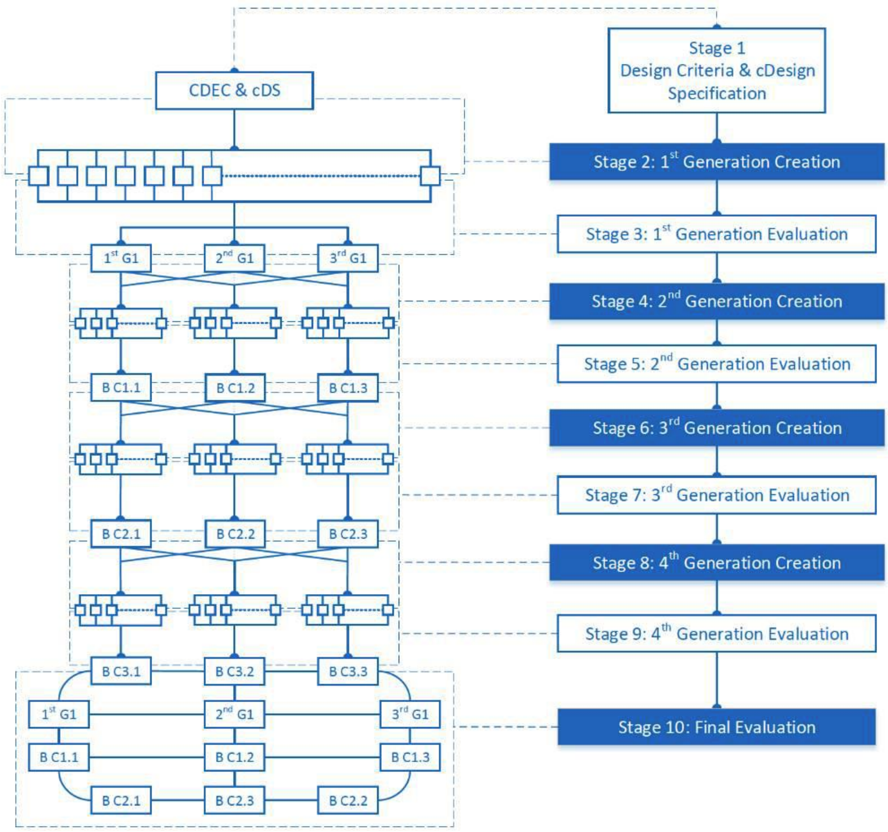

Figure 2. Workflow of the car key fob design experiment

Stage 1: cDesign Specification & cDesign Evaluation Criteria

To create the design specification (which will also form the basis of the evaluation criteria) the crowd was asked to provide answers to the following questionnaire:

1. Could you please suggest 5 features, or functions, that a remote car key fob should have to be suitable for elderly users/drivers?
2. Could you please suggest 3 further features, or additional functions, that a remote car key fob should have?

As previously reported a ‘coding’ method was applied to qualitatively collected and integrated all design criteria generated by the crowd (Hao Wu et al., 2015).

Stage 2: 1st Generation Creation

The first design task of the experiment was posted on mTurk as: car key fob drawing task. In the task, participants were required to generate a car key fob drawing by free-hand drawing, and then copy (i.e., photograph or scan) their drawings to the requester. During the drawing, the specifications are shown to participants, and they are required to meet the specifications.

Stage 3: 1st Generation Evaluation

In cDesign framework, after the design creation task, all generation 1 designs needed to be evaluated by the crowd against the cDEC (crowdsourced design evaluation criteria). Participants evaluate drawings from the generation 1 by the cDEC collected from the crowd. Firstly, a 7-Point Likert Scale is provided to participants to rate drawings from a range of 1 (worst drawings) to 7 (best drawing). Secondly, based on their rating scores, drawings need to be ranked in the group. Thirdly, participants are required to provide reasons for the top three rankings. Any step missed in their submissions, the results will be rejected. Based on the evaluation results of the 1st generation car key fob drawings, the top three drawings will be combined by their best features to generate the next generation designs following the cDesign framework.

Stage 4: 2nd Generation Creation (Combination 1)

In the 2nd generation car key fob creation task, participants need to combine the best features from the 1st generation drawings based on the ranking results. In the cDesign framework, following the Human-based Genetic Algorithm, new generation comes from its last generation. In this stage, because only the top three drawings will be combined, so in total each generation can create $C\frac{2}{3} = \frac{3! \div 2!}{(3-2)!} = 3$ new groups of designs. In each new combination group, ten approved drawings are required to collected (Figure 3). The combination process is shown below (G1 means 1st generation). So the new drawings created in this stage are 2nd generation drawings. When collected all thirty drawings (ten in each group), the drawings will be evaluated again.

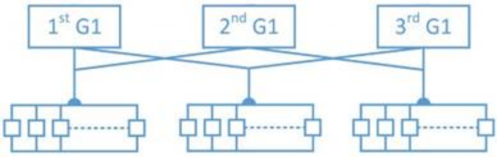

Figure 3. Design combination process – 2nd generation creation

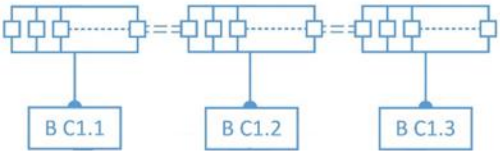

Figure 4. 3rd generation evaluation

Stage 5: 2nd Generation Evaluation

The same as the 1st generation evaluation stage, all ten-car key fob conceptual drawings will be evaluated among all drawings in each group. Participants are also required to rate and rank designs from first place to tenth place. The best drawing in each group will be used to create the 3rd generation. (See in Figure 4: B C1.1 means the best drawing in the combination 1, group 1; B C1.2 means the best drawings in the combination 1, group 2. CN (Combination N) = G(N+1) (Generation N+1)).

Stage 6: 3rd Generation Creation (Combination 2)

In Stage 6, the best features of the best designs from the previous evaluation results will be combined to create the new 3rd generation designs. Repeating the process in the 2nd generation creation task, three new groups of designs are generated. The power of the crowdsourcing approach is demonstrated by this process since the subjective judgement of what constitute the "best" features and how they should be combined is delegated to the human work rather than computational algorithms.

Stage 7: 3rd Generation Evaluation

The process of Stage 5 is repeated in this stage.

Stage 8: 4th Generation Creation (Combination 3)

The process of Stage 4 and 6 is repeated in this stage.

Stage 9: 4th Generation Evaluation

In this stage, all 4th generation drawings will be evaluated in their respective group. So the experiment can create the final outputs by this stage of the car key fob conceptual drawings.

4 EXPERIMENT RESULTS

This experiment involved a number of 456 participants in the design creation and evaluation tasks (including the cDS & cDEC collection task). The age ranges from the youngest 17 years old to the oldest 65 years old. Moreover, participants were from over 20 countries, and over 62% of them did not have any design experience before. Over 75% of them had a college degree or higher. Furthermore, over 97% of the participants drive cars (an important consideration since this is a car key fob design experiment).

In Stage 1, five functional requirements (i.e., cDEC/cDS) were collected: 1) doors lock/unlock, 2) security, 3) engine start, 4) GPS function and 5) car information display (i.e., fuel and electrical battery information). Participant's design and evaluation of conceptual designs used these functional requirements.

Figure 5. Examples of the 1st generation car key fob designs

In the 1st generation, 170 approved car key conceptual drawings were submitted by participants (examples of the drawings from the 1st generation is shown below in Figure 5). After the 1st generation evaluation stage, the top three ranked drawings were illustrated in Figure 6, which are No. 78, No. 64 and No. 147.

Following the experimental workflow, those highest ranked drawings were combined (as figure) to create the 2nd generation of car key fobs (combination 1). Then participants evaluated each individual combination group to rank the highest drawings. As a result, C1.1.1, C1.2.8 and C1.3.4 were combined to create the next generation (the nomenclature CN.α.β means in combination N, group α, no. β drawing. For example, C1.2.8 means in the combination 1 generation, group 2, no. 8 – each group required ten drawings) (Figure 7). Similarly, the 3rd and 4th generation were created by the same design evaluation method (Figure 8 and Figure 9). Finally, in the evaluation stage for the 4th generation, the best three ranked drawings are shown as follow (Figure 10).

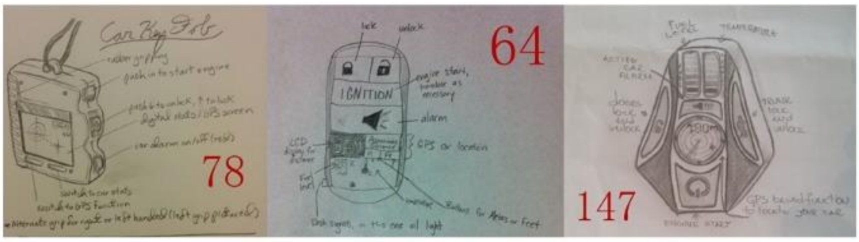

Figure 6. The 1st generation designs that crowd judges had "best" incorporated the required functions

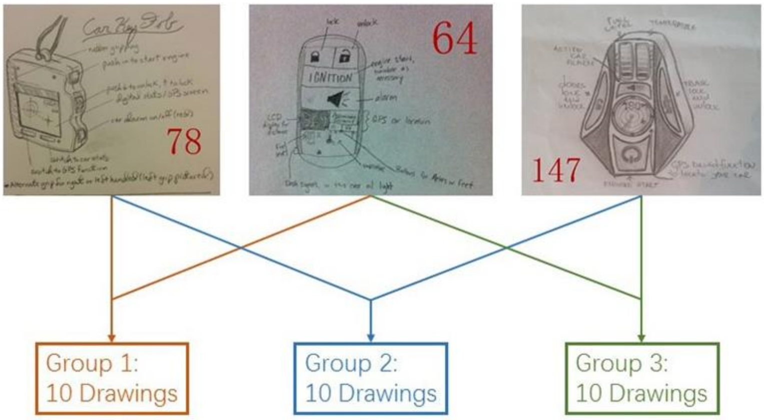

Figure 7. Combined process of top three ranked drawings from the 1st generation

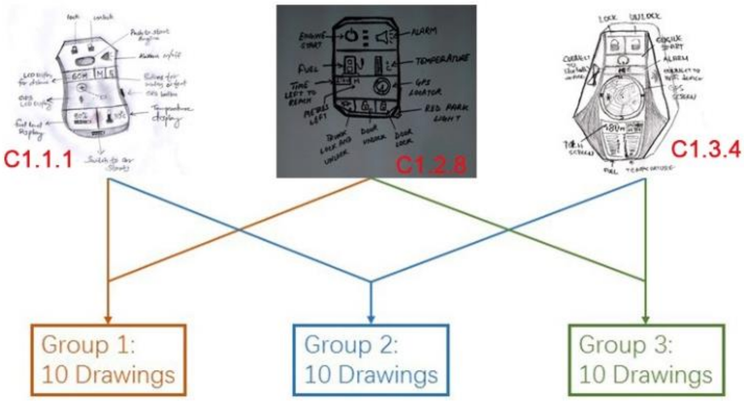

Figure 8. Combined top three drawings from the 2nd generation

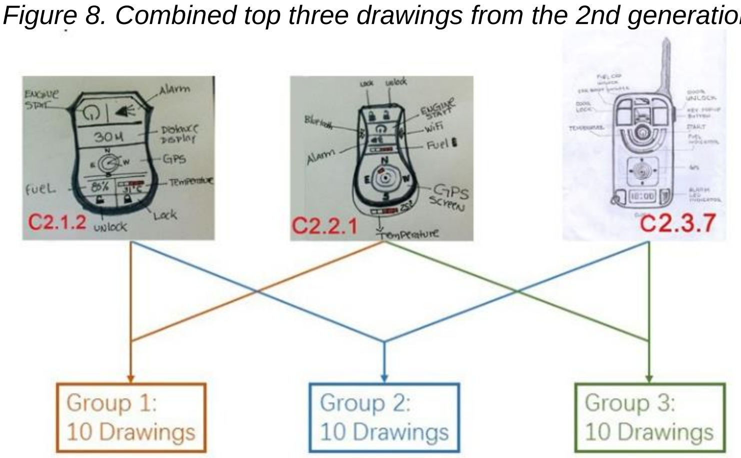

Figure 9. Combined top three drawings from the 3rd generation

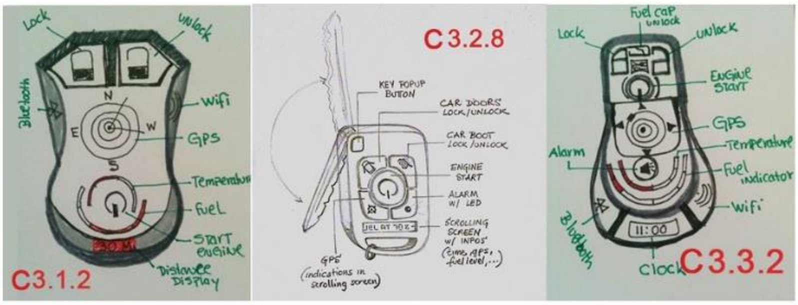

Figure 10. Best three ranked drawings in the 4th generation

5 DISCUSSION

In previously reported applications of the cDesign Framework to the generation of living room floor plan and 3D kitchen plans open, cloud based design tools (i.e., Google Drawing, Autodesk Homestyler) had been used, in contrast the results here demonstrate improving design quality by using free-hand sketches and functional evaluation criteria.

To verify the process had improved design quality after the iterative design and evaluation stages of the experiment, the best three drawings in the 4th generation and the best three drawings in the 1st generation were evaluated together using the same evaluation method employed throughout the experiment (e.g., crowd rank against five criteria). The results are as follows: the highest ranked drawing is C3.2.8, then is C3.1.2 followed by No. 64 (ranking results are shown in Table 1). This suggests that among the best three drawings, 2/3 comes from the last generation of car key fob conceptual drawings, which confirmed that after employing an HBGA process (that was structured using the cDesign Framework), the final output of design quality was improved.

Table 1. Ranking of the First and Last design generations

Drawing No.	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8	Rank 9	Rank 10	Average Ranking
3.3.2	3	2	3	5	4	2	6	6	5	5	5
147	2	6	2	4	1	5	1	4	4	6	4
64	**4**	**1**	**1**	**3**	**6**	**6**	**3**	**3**	**2**	**4**	**3**
3.2.8	**6**	**3**	**4**	**2**	**2**	**4**	**4**	**1**	**1**	**2**	**1**
78	1	4	6	6	5	3	2	5	6	3	6
3.1.2	**5**	**5**	**5**	**1**	**3**	**1**	**5**	**2**	**3**	**1**	**2**

6 CONCLUSION, LIMITATION AND FUTURE WORK

In this paper, a car key fob design experiment on mTurk was described. This design experiment applied the authors' cDesign Framework, and used the HBGA crowdsourced design method to systematically improve the design quality. Specially, the free-hand sketch design method is firstly in the cDesign framework based design process. Differently from other experiment used cDesign framework (Wu et al., 2014b; Hao Wu et al., 2015; Wu et al., 2014a), in this crowdsourced design task, because a free-hand sketch method was used to generate designs. The first step for participants of uploading their submission was to transfer their work into digital format (i.e., photo of sketch, scanned copy of sketch, etc.), then submitted them to participants.

In total, four generations of drawings were created by the crowd and evaluated. During the design creation stage, the best features from each pair of drawings were combined by the human workers to generate the new drawings. The process of evaluation and combination repeated to generate better quality of designs. The final evaluation shows that in this car key fob design task, the process resulted in improved conceptual design quality by a comparison between the last generation designs and the first-generation designs. The results have not only demonstrated that the free-hand sketch method can be effectively used in a multi-stage (i.e., iterative) crowdsourcing process but have also provided a benchmark for the numbers of participants required to successfully carry-out a design task in this way. While many more trails will be required to establish if there is a general relationship exists between 'crowd size' and 'degree of design improvement', these results at least provide a first data point. However, this work has limitations. Although the experiments validate the effectiveness of cDesign Framework for concept sketches, it is still unknown that how a crowdsourced design process (structured by the cDesign Framework) will perform in a real product design projects. In the future, a series of design case studies are required to validate the application of the cDesign Framework in product design tasks that progress to the detailed prototype stage (beyond concept sketches). It would also be interesting to investigate that the difference between Collaboration Design process and Crowdsourced Design in design tasks.

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